PHYS 410: Quantum Mechanics

Term: Fall 2026
Credits: 4.0
Seminar Times & Location: Monday, Tuesday, Wednesday, Friday 1:00–1:50 p.m., Meridian Science Center 170
Modality: In-Person Seminar

Instructor Information

- **Instructor:** Dr. William Thorne (Professor of Physics)
- **Email:** wthorne@university.alkimi.ai
- **Office:** Meridian Science Center 410
- **Office Hours:**
  - Monday & Thursday: 10:00–11:30 a.m. (In person, Meridian Science Center 410)
  - Wednesday: 3:00–4:00 p.m. (Virtual via Zoom; link posted in Canvas)
  - Also available by appointment.

Course Description

Wave functions and operators, the Schrödinger equation in one and three dimensions, the harmonic oscillator, the hydrogen atom, angular momentum and spin, identical particles, and perturbation theory. PHYS 410 is an advanced, mathematically formal study of non-relativistic quantum mechanics for senior physics majors. Formulating the theory in Hilbert space using Dirac bra-ket notation, we investigate state vectors, Hermitian operators, observables, and generalized uncertainty relations. The course thoroughly develops the quantum harmonic oscillator via ladder operators, central force problems, orbital and spin angular momentum addition, systems of identical particles, and time-independent perturbation theory.

Prerequisites

PHYS 221, MATH 250, and MATH 340.

Measurable Student Learning Outcomes

Upon successful completion of PHYS 410, students will be able to:

1. **Apply Hilbert Space Formalism and Dirac Notation:** Operate with state vectors, projection operators, Hermitian observables, and unitary transformations in finite and infinite-dimensional Hilbert spaces.
2. **Solve the Quantum Harmonic Oscillator Analytically and Algebraically:** Derive energy eigenvalues and eigenfunctions of the harmonic oscillator using both differential equations and raising/lowering operator techniques.
3. **Analyze Angular Momentum and Spin Coupling:** Calculate commutation relations for orbital and spin angular momentum operators, determine eigenvalue spectra, and compute Clebsch-Gordan coefficients.
4. **Solve Three-Dimensional Central Potentials:** Solve the radial Schrödinger equation for spherical potentials, derive the hydrogen atom spectrum, and construct radial wavefunctions and spherical harmonics.

5. **Evaluate Many-Particle Systems and Exchange Symmetry:** Construct symmetric and antisymmetric states for systems of identical bosons and fermions, analyzing exchange forces and the helium atom ground state.
6. **Implement Time-Independent Perturbation Theory:** Calculate first- and second-order energy shifts and wave function corrections for non-degenerate and degenerate systems, applying techniques to fine structure and Zeeman effects.

Required Course Materials & Approximate Costs

1. **Griffiths, David J., and Darrell F. Schroeter. *Introduction to Quantum Mechanics*. 3rd ed., Cambridge University Press, 2018.** Approx. $60 for digital; approx. $85 for print purchase.
2. **Total estimated cost:** $60 to $85.

Generative AI Policy (AI Level 2: AI Permitted with Disclosure for Specified Tasks)

In accordance with Alkimi University Academic Policies (Student Handbook §5.8), PHYS 410 operates under **AI Level 2**.

- **What is permitted:** You may use AI tools to check matrix diagonalizations, verify commutators between operators, explore Dirac bra-ket notation manipulations, and generate practice problems for perturbation theory.
- **What is prohibited:** You may not submit AI-generated derivations or proofs for weekly homework problem sets, copy AI solutions for take-home or in-class exams, or consult any generative AI during examinations.
- **Disclosure:** Provide a written statement at the end of every submitted problem set indicating which AI tools were consulted and explaining your independent verification of all quantum calculations, or confirm no AI tools were used.

Grading Components and Weights

- **Midterm Exam 1:** 20% (In class, Friday, September 25)
- **Midterm Exam 2:** 20% (In class, Friday, October 30)
- **Weekly Advanced Problem Sets:** 25% (Due Fridays at 11:59 p.m. in Canvas (weeks 2–13; lowest dropped))
- **Quantum Mechanics Term Paper:** 10% (Due Friday, November 20 at 11:59 p.m.)
- **Final Comprehensive Examination:** 25% (Wednesday, December 16, 2026, 3:30–5:30 p.m.)

Grading Scale (Alkimi University Standard)

- **A:** 93–100% | **A-:** 90–92%
- **B+:** 87–89% | **B:** 83–86% | **B-:** 80–82%
- **C+:** 77–79% | **C:** 73–76% | **C-:** 70–72%
- **D+:** 67–69% | **D:** 60–66% | **F:** Below 60%
- **Extra credit:** No extra credit assignments are offered in PHYS 410.

Course Schedule (Fall 2026)

Week	Dates	Topics & Readings	Assignments & Deadlines
Week 1	Aug 26, 28	**Wave Function Formalism and Probability Current:** Born interpretation, normalization condition, continuity equation for probability, expectation values, and momentum operator in position space. *Reading: Griffiths Ch. 1*	*First day of classes: Wed Aug 26.*
Week 2	Aug 31–Sep 4	**Stationary States and the Infinite Square Well:** Time-independent Schrödinger equation, energy quantization, parity,	*Wed Sep 2: Add/section change deadline.*

Week	Dates	Topics & Readings	Assignments & Deadlines
		boundary conditions, completeness, and orthonormality of stationary states. *Reading: Griffiths Ch. 2.1–2.2*	
Week 3	Sep 8–11	**Harmonic Oscillator: Power Series Solution:** Asymptotic behavior, Hermite polynomials, generating functions, Rodrigues formula, and orthogonal wave functions. *Reading: Griffiths Ch. 2.3.1*	*Mon Sep 7: Labor Day (no classes). Wed Sep 9: Census date (last day to drop without a W).*
Week 4	Sep 14–18	**Harmonic Oscillator: Algebraic Operator Method:** Commutation relations, raising and lowering ladder operators, ground state derivation, energy spectrum, and matrix elements. *Reading: Griffiths Ch. 2.3.2*	—
Week 5	Sep 21–25	**Free Particles and Wave Packets & Midterm Exam 1:** Continuous spectrum, Fourier transforms, group versus phase velocity, delta-function potential well; Midterm Exam 1 in class. *Reading: Griffiths Ch. 2.4–2.5*	**Midterm Exam 1 (in class).**
Week 6	Sep 28–Oct 2	**Scattering States and Finite Wells:** Transmission and reflection coefficients, scattering matrix formalism, resonance scattering, and bound states in finite potential wells. *Reading: Griffiths Ch. 2.6*	—
Week 7	Oct 5–9	**Hilbert Space and Dirac Bra-Ket Notation:** Linear vector spaces, inner products, dual spaces, Dirac bras and kets, projection operators, Hermitian adjoints, and unitary operators. *Reading: Griffiths Ch. 3.1–3.3*	—
Week 8	Oct 14, 16	**Generalized Uncertainty Principle and Observables:** Commuting observables, simultaneous eigenfunctions, generalized Robertson-Schrödinger uncertainty relation, and continuous spectra. *Reading: Griffiths Ch. 3.4–3.6*	*Oct 12–Oct 13: Fall break (no classes).*
Week 9	Oct 19–23	**Schrödinger Equation in Three Dimensions:** Separation of variables in spherical coordinates, angular equation, Legendre polynomials, and radial differential equation. *Reading: Griffiths Ch. 4.1*	—
Week 10	Oct 26–30	**The Hydrogen Atom & Midterm Exam 2:** Coulomb potential, associated Laguerre polynomials, Bohr radius, energy eigenvalue formula, and hydrogenic wave functions; Midterm Exam 2 in class. *Reading: Griffiths Ch. 4.2*	**Midterm Exam 2 (in class).**
Week 11	Nov 2–6	**Orbital Angular Momentum:** Angular momentum ladder operators, spherical harmonics Y_lm, eigenvalues of L^2 and L_z, and spatial rotation generators. *Reading: Griffiths Ch. 4.3*	*Fri Nov 6: Last day to withdraw (W) or elect Pass/No Pass.*
Week 12	Nov 9–13	**Spin and Two-Level Systems:** Spin 1/2 algebra, Pauli spin matrices, spinor wave functions, Stern-Gerlach apparatus, magnetic dipole moments, and Larmor precession. *Reading: Griffiths Ch. 4.4.1*	—
Week 13	Nov 16–20	**Addition of Angular Momenta:** Coupled and uncoupled bases, total angular momentum J = L + S, Clebsch-Gordan coefficients, and selection rules. *Reading: Griffiths Ch. 4.4.2–4.4.3*	**Quantum Mechanics Term Paper due Fri Nov 20 at 11:59 p.m.**
Week 14	Nov 23, 24	**Identical Particles and Multi-Electron Systems:** Two-particle systems, exchange operator, symmetric (bosons) and antisymmetric (fermions) wave functions, Pauli exclusion principle, and ortho/para-helium. *Reading: Griffiths Ch. 5.1–5.2*	*Nov 25–Nov 27: Thanksgiving break (no classes).*
Week 15	Nov 30–Dec 4	**Time-Independent Non-Degenerate Perturbation Theory:** Perturbation expansion, first-order energy corrections, first-order wave function corrections, second-order energy shifts, and anharmonic oscillator. *Reading: Griffiths Ch. 7.1*	—
Week 16	Dec 7–9	**Degenerate Perturbation Theory and Fine Structure:** Degenerate perturbation theory, relativistic kinetic energy correction, spin-orbit interaction, Darwin term, fine structure of hydrogen, and review. *Reading: Griffiths Ch. 7.2–7.3 & Review*	*Wed Dec 9: Last day of classes. Thu Dec 10: Reading Day.*

Week	Dates	Topics & Readings	Assignments & Deadlines
Finals	Dec 16	**Final Comprehensive Examination:** Wednesday, December 16, 2026, 3:30–5:30 p.m., Meridian Science Center 170.	Comprehensive examination covering Hilbert space formalism, angular momentum, identical particles, and perturbation theory.

Course Policies

Attendance Policy

Attendance at every seminar meeting is mandatory. Advanced quantum mechanics requires collaborative chalkboard derivations, rigorous conceptual dialogue, and active questioning. If you must miss a class due to illness or academic conference travel, notify Dr. Thorne via email in advance. More than three unexcused absences will result in a penalty to your final course grade. Students who miss the first two class meetings without notifying the instructor may be dropped. Students may miss class for religious observance without penalty if they notify the instructor in writing within the first two weeks of the semester (by Wednesday, September 9, 2026). Absences for university-sponsored activities (athletics, performances, conferences) are excused with a letter from the sponsoring office at least one week in advance.

Late Work Policy

Problem sets submitted within 24 hours of the Friday deadline receive a 20% penalty. Because solution packets are distributed immediately thereafter, no problem sets will be accepted after 24 hours. The single lowest weekly problem set score will be dropped.

Final Exam Policy

The final examination (Wednesday, December 16, 2026, 3:30–5:30 p.m.) is scheduled by the University Registrar and can't be moved without the Dean's written approval (Faculty Handbook §5.5). A student with three or more final exams on the same calendar day may reschedule one of them. Requests go to the instructor of the middle exam by the last day of classes. For this term, send the request by Wednesday, December 9, 2026 (Student Handbook §6.4).

Academic Integrity

Alkimi University is an academic community devoted to rigorous scholarship, open intellectual inquiry, and uncompromising ethical conduct. All students are subject to the regulations of the Alkimi University Academic Integrity Policy. Academic dishonesty—including plagiarism, cheating on examinations, unauthorized collaboration, fabrication of empirical data, and unauthorized submission of academic work generated by artificial intelligence—undermines the integrity of the university and carries severe disciplinary sanctions. Sanctions range from a failing grade on an assignment or exam to an administrative course failure recorded as an 'XF' on the official transcript, academic suspension, or expulsion. Suspected violations are formally investigated and resolved through the Office of Academic Integrity in accordance with Faculty Handbook §6. For detailed information, consult the Office of Academic Integrity, Lovell Hall 315, (555) 555-0163, integrity@university.alkimi.ai.

Accessibility Services

Alkimi University is committed to providing equitable educational access and reasonable accommodations for all students with documented disabilities, including physical, sensory, psychological, learning, and chronic health conditions. Students requesting academic accommodations must formally register with the Office of Accessibility Services, Harlan Hall 204, (555) 555-0155, access@university.alkimi.ai. Once approved, students will receive an official Faculty Accommodation Letter detailing approved accommodations. Students should present this letter to the instructor as early in the semester as possible, and at least one

week prior to any exam or assignment requiring accommodation. Accommodations cannot be applied retroactively.

Student Wellness and Mental Health

Your physical health, psychological well-being, and mental health are essential to your academic success. If you experience heightened stress, anxiety, depressive symptoms, personal trauma, or academic burnout, free, confidential counseling and medical care are available through the Hollis Health & Counseling Center, located in the Hollis Center. Routine appointments are available Monday–Friday 8:00 a.m.–6:00 p.m. and Saturday 10:00 a.m.–2:00 p.m. during the semester by calling (555) 555-0190 or emailing health@university.alkimi.ai. Urgent, 24/7 crisis psychological counseling is accessible immediately at (555) 555-0199.

Campus Student Support Services

- **Academic Advising Center:** Lovell Hall 101 | (555) 555-0158 | advising@university.alkimi.ai
- **Writing Center:** Whitcombe Library 3rd Floor | Free consultations on papers, reports, and research projects at any stage.
- **Whitcombe Library:** Whitcombe Library, Main Floor | (555) 555-0170 | askalibrarian@university.alkimi.ai
- **Hollis Health & Counseling Center:** Hollis Center | (555) 555-0190 | 24/7 Counseling Line: (555) 555-0199 | health@university.alkimi.ai
- **Physics Tutoring Center:** Drop-in peer tutoring and conceptual assistance are available Monday through Thursday from 2:00 to 6:00 p.m.